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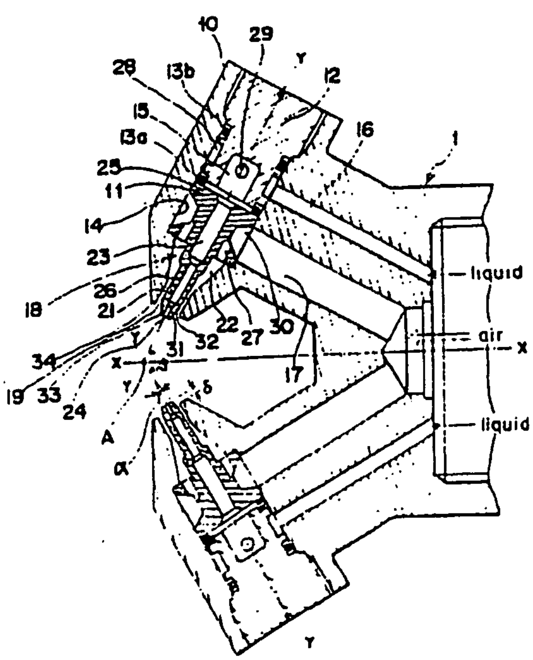
(54) Atomizer nozzle assemble.

(57) The disclosure relates to an atomizer nozzle assembly for producing an extrafine mist of liquid. In the nozzle assembly, a liquid passage hole (23)of each nozzle tip (11) extends along a longitudinal axis (Y-Y) of the nozzle tip and has a front end opening (24) centrally formed in the front end face (33) of the nozzle tip. The angle (α) of taper of a front tapered portion of each nozzle tip is 16° - 24°. Through above arrangement it is possible to produce a substantially ultrafine mist at the start of atomizing operation and also to produce an ultrafine mist having a constant particle diameter with the rise in pressure immediately following the start of atomization under an initial pressure of compressed air.

Fig. 3



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Atomizer Nozzle Assembly

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention generally relates to a nozzle for an atomizer which produces a jet of liquid in the form of a mist and, more particularly, to a nozzle assembly applicable to an ultrafine particle atomizer of a type which produces an extrafine mist of liquid, such as water, fuel oil, or medical solution, having a mean particle diameter (Sauter mean particle diameter; same applicable hereinafter) ranging from a submicron to some ten microns at most, or in other words, a dry mist which does not feel wet if touched by hand (which is referred to as "ultrafine mist").

2. Prior Art

Atomizers are employed in various fields for various purposes, such as humidifying, cooling, dust controlling, disinfectant solution spraying, and fuel oil atomizing. Generally, it is desirable that any mist produced by means of such device should be an ultrafine mist. The reason is that if component particles of the mist are coarse, circumjacent objects will get wet on their surface in a given period of time in cases where, for example, the atomizer is employed for humidifying purposes; and if the atomizer is employed for the purpose of disinfectant solution spraying, the circumjacent objects will get wet with the result of stains being left thereon.

The present inventor, after his series of study on such problem, found that an ultrafine mist must be such that its component liquid particles be not greater than 50 microns in maximum particle diameter and not more than some ten microns in Sauter mean diameter. On the basis of such finding, the present inventor has already proposed various ultrafine mist producing atomizers (Japanese Published Unexamined Patent Application Nos. 54-111117, 55-49162, and 57-42362).

There are two types of nozzle assemblies, one or the other of which is employed in the ultrafine mist producing atomizers proposed by the present inventor. One type is such that compressed air is caused to pass through a passage outside the nozzle tip, which may be called the outer air-passage type (Japanese Published Unexamined Patent Application Nos. 55-49162 and 57-42362). The other type is such that compressed air is caused to pass through a passage defined within the nozzle tip, which may be called the inner air-passage type (Japanese Published Unexamined Patent Application No. 54-111117). From the standpoint of preventing the diffusion of a jet stream of a gas-liquid mixture from the nozzle orifice, it is generally believed that nozzles of the outer air-passage type are preferable.

To illustrate a nozzle of the outer air-passage type, general arrangement of the nozzle in the ultrafine mist producing atomizer disclosed in said patent publication No. 55-49162 is described below by way of example.

The basic arrangement of this nozzle is generally identical with that shown in Figs. 1 and 2, which represents one embodiment of the present invention. That is, a nozzle body has a plurality of nozzle heads arranged in equi-spaced relation around the longitudinal axis thereof, each of the nozzle heads having a mounting hole in which a nozzle tip is mounted. Each nozzle tip, as can be seen from Fig. 12 (in which a part of a nozzle is shown), has a liquid passage hole 5a, while there is defined an air jet passage 5e between a mounting hole 5b in a nozzle body 5c and the outer periphery of a nozzle tip 5d. Individual mounting holes and individual nozzle tips are so arranged that the respective longitudinal axes of the nozzle tips converge at one point on the longitudinal axis of the nozzle body, whereby as currents of compressed air are caused to jet out toward said one point on the longitudinal axis of the nozzle body passing through the air jet passages, they suck liquid thereinto through the respective front end openings 5f of the liquid passage holes to form jet streams of a gas-liquid mixture so that the jet streams impinge against one another at said one point on said longitudinal axis, thereby producing an ultrafine mist of liquid.

With respect to the above described prior-art nozzle arrangement, it must be noted that, as Fig. 12 shows, the front end openings 5f of the liquid passage hole 5a defined in each nozzle tip 5e open at sides of the front end 5g of the tip and not on the front end 5g itself; that the angle of taper of a front end tapered portion 5h of the nozzle tip 5d is about 7° - 22°; and that the front end of the nozzle tip 5d projects little, if any, from the nozzle body 5c (the amount of such projection being of the order of 0.2 mm at most).

Now, in the prior-art nozzle of such arrangement, the relationship between compressed air pressure and liquid atomization rate shows such pattern of trend as shown in Fig. 4a (conditions in Fig. 4 are: liquid pressure = 0; liquid suction height = 100 mm). In other words, there is no proportional relationship between compressed-air

pressure and liquid atomization rate. In the Fig. 4a case, the mean particle diameter in the mist is about 50 microns - about 10 microns in a low pressure zone of from an initial air pressure at which atomization starts and up to a pressure level of about 3 kg/cm², no ultrafine mist being available; an ultrafine mist having a mean particle diameter of less than about 10 microns is produced only in a high pressure zone in which the air pressure is in excess of about 3 kg/cm²; however, as the air pressure becomes higher, the mean particle diameter becomes smaller, and in the Fig. 4a case, atomization is terminated when an air pressure of less than 4 kg/cm² is reached. With aforesaid prior-art arrangement, therefore, one difficulty is that at on/off control stages for compressed air supply, a mist having a relatively coarse particle size is produced, so that the floor and circumjacent surfaces will get wet. Another difficulty is that where only a small amount of ultrafine mist is required, it is necessary to increase the air pressure, which means a disproportionally greater air consumption for the liquid atomization requirement; this is extremely uneconomical. A further difficulty is that the diameter of particles in the mist varies with changes in air pressure, or in other words, no mist having a constant particle diameter can be produced.

These problems are considered to be attributable to the front end structure of the nozzle and, more particularly, to the fact that it causes a negative pressure to develop as a compressed air current passes at a supersonic velocity through the nozzle orifice, and the resulting pattern of compressed air flow.

SUMMARY OF THE INVENTION

It is, therefore, an essential object of the present invention is to provide an atomizer nozzle assembly having an improved front end structure which is likely to cause a negative pressure and the pattern of compressed air flow, thereby enabling a substantially ultrafine mist to be produced at a point of time when atomization is initiated under an initial pressure of compressed air, also enabling an ultrafine mist to be produced when a slightly higher level of air pressure is reached, at a flow rate generally proportional to the pressure rise.

In accomplishing this and other objects, according to the present invention, there is provided an atomizer nozzle assembly comprising the following arrangement:

In a nozzle assembly generally identical with above described prior-art arrangement, a liquid passage hole of each nozzle tip extending along the longitudinal axis of the nozzle tip has a front end opening centrally formed in the front end of the nozzle tip. The angle of taper of a front tapered portion of each nozzle tip is 16° - 24°.

Such arrangement of the invention is based on the findings of certain experiments which will be described hereinafter. Through such arrangement it is possible to produce a substantially ultrafine mist at the start of atomizing operation and also to produce an ultrafine mist having a constant particle diameter with the rise in pressure immediately following the start of atomization under an initial pressure of compressed air.

Therefore, according to the invention, there will be no generation of any coarse particle mist at on/off stages for compressed air jetting, there being thus no possibility of such mist wetting the floor and other circumjacent surfaces. Further, with a rise in the pressure of compressed air, an ultrafine mist having a generally uniform particle diameter can be produced at a rate proportional to the pressure rise.

In the foregoing arrangement, it is desirable that the front end of each nozzle tip should project forward from the front end of the corresponding nozzle tip, and that the length of such projection be set within the range of 0.3 -0.8 mm. Through such arrangement it is possible to ensure atomization in stable condition. That is, by so arranging that the front end of each nozzle tip projects forward more than 0.3 mm, it is possible to produce a steady jet stream of a gas-liquid mixture, because droplets of liquid sucked outward from the liquid passage hole become less inclined to be attracted toward an enlarged portion defined between the front tapered portion of the nozzle tip and the interior of the nozzle head, that is, in a back flow direction, while on the other hand by limiting the length of the nozzle tip projection to not more than 0.8 mm it is possible to control the maximal diameter of liquid particles in a mist to not more than 50 microns, the permissible maximum particle diameter for an ultrafine mist.

It is to be noted in this conjunction that if the front end opening of the liquid passage hole in the nozzle tip is reverse tapered, it is possible to obtain an ultrafine mist having a more uniform particle diameter.

BRIEF DESCRIPTION OF THE DRAWINGS

This and other objects and features of the present invention will become apparent from the following description taken in conjunction with the preferred embodiment thereof, with reference to the accompanying drawings, in which:

Figs. 1 and 2 are, respectively, a side view and a right end view, both showing an atomizer nozzle assembly in accordance with the invention;

Fig. 3 is an enlarged view in longitudinal section showing the nozzle in Figs. 1 and 2;

Fig. 3a is a fragmentary sectional view showing a modified form of the nozzle in Fig. 3;

Fig. 4a is a graphic representation showing the relationship between air pressure (abscissa) and liquid atomization rate (ordinate) in the case where the prior-art nozzle shown in Fig. 12;

Fig. 4b is a graph showing the relationship between air pressure (abscissa) and liquid atomization rate (ordinate) on the basis of the results of experiments conducted by employing the nozzle embodying the invention;

Fig. 5 is a graph showing the relationship between the angle of taper (α) at the nozzle tip front end (abscissa) and maximal liquid drop particle diameter (ordinate) on the basis of the results of experiments conducted by employing the nozzle of the invention;

Fig. 6 is a graph showing the relationship between liquid atomization rate (abscissa) and air consumption (ordinate) on the basis of the results of experiments conducted by employing the nozzle of the invention;

Fig. 7a is a graph showing the relationship between particle diameter (abscissa) and number of particles (ordinate) in the case where one of the discharge ports in the nozzle assembly according to the invention was closed so that the nozzle assembly was employed as a single-head nozzle;

Fig. 7b is a graph showing the relationship between particle diameter (abscissa) and number of particles (ordinate) in the case where the double head nozzle according to the invention was employed as such;

Fig. 8a is an explanatory view showing the condition of gas-liquid flow in the case where the front end of the nozzle tip involves little projection from the nozzle body;

Fig. 8b is an explanatory view showing the condition of gas-liquid flow in the case where the front end of the nozzle tip projects forward 0.3 mm from the nozzle body;

Fig. 9a is a graph showing the relationship between liquid atomization rate (abscissa) and degree of angle (ordinate) according to Fig. 8a;

Fig. 9b is a graph showing the relationship between liquid atomization rate (abscissa) and degree of angle (ordinate) according to Fig. 8b;

Fig. 10 is a graph showing the relationship between the amount of nozzle tip projection (abscissa) and maximal particle diameter (ordinate);

Fig. 11 is a graph showing the relationship between air pressure (abscissa) and compressed air temperature (ordinate), and also showing liquid droplet freezing temperatures; and

Fig. 12 is a fragmentary sectional view showing a prior-art nozzle, as previously described.

DETAILED DESCRIPTION OF THE INVENTION

One preferred embodiment of the present invention will now be described in further detail in conjunction with experimental examples.

Figs. 1 and 2 illustrate general aspects of a nozzle assembly in accordance with the invention. The nozzle assembly consists generally of a nozzle body (1) and an adapter (2) for air and water supply which is connected to the nozzle body 1. The nozzle body 1 has a plurality of nozzle heads (10) arranged in equi-spaced relation around its center line, that is, the longitudinal axis (X - X) thereof.

The number of nozzle heads (10) is not particularly limited. In the present embodiment, the nozzle body (1) has two nozzle heads. That is, the nozzle assembly is of a two-head nozzle construction.

Fig. 3 is an enlarged sectional view of the nozzle body (1) shown in Figs. 1 and 2. As shown, each nozzle head (10) of the nozzle body 1 has an air introduction path (17) for introducing compressed air thereinto, and a liquid introduction path 16 for introducing liquid, such as water or disinfectant solution, according to the purpose for which the atomizer is to be employed. The air introduction path (17) and the liquid introduction path (16) are respectively connected at one end to a compressed air introduction path and a liquid introduction path, both formed in the adapter 2.

Each nozzle head (10) has a mounting hole (14) for housing or mounting a nozzle tip (11) therein. As shown, the nozzle tip (11) is housed in the mounting hole (14) at the front end side thereof, being fixed by a plug (12) housed in the hole (14) at the rear end side thereof.

Individual nozzle heads (10) and individual nozzle tips (11) housed therein are so arranged that the respective longitudinal axes (Y - Y) of the nozzle tips (11) converge at one particular point (A) on aforesaid longitudinal axis (X - X). Generally,

the angle (β) at which a pair of longitudinal axes (Y - Y), (Y - Y) intersect each other is preferably set at 70° - 160°. The distance between a pair of nozzle orifices is generally preferably set at 3 - 15 mm.

The mounting hole (14) in each nozzle head (10) is of a generally cylindrical configuration, and its front end portion includes a forwardly tapered portion (22) and a discharge port (19) of a smaller diameter cylindrical configuration continued from the tapered portion (22).

Each nozzle tip (11) consists generally of a large diameter base portion (25) and a small diameter front portion (26). The liquid passage hole (23) of the nozzle tip (11) extends along the longitudinal axis (Y - Y) of the nozzle tip (11) and has a front end opening (24) which is open centrally in the front end (33). This front end opening (24) may be of such a straight configuration as shown in Fig. 3, or may be of such a slightly divergent configuration as shown in Fig. 3a. The large diameter base portion (25) is in contact with the cylindrical interior of the mounting hole (14), while the small diameter front portion (26) projects slightly outward passing through the tapered portion (22) of the mounting hole (14) and then through the discharge port (19) (the length of projection = δ). The large diameter base portion (25) of each nozzle tip (11) has a circumferential groove or communicating groove (30) formed on its outer periphery, and also has a communicating hole (27) which communicates between the communicating groove (30) and the space in the tapered portion (22) of the mounting hole (14). The air introduction hole (17) is open toward the communicating groove (30) for communication therewith. Accordingly, the compressed air supplied through the air introduction hole (17) is allowed to pass through an air discharge path (18) formed on the outer periphery of the small diameter front portion (26), that is, the tapered portion (22) and the discharge port, via said communicating groove (30) and said communicating hole (27), until it is jetted out. The small diameter front portion of the nozzle tip (11) is inserted into the discharge port (19) to form a throat portion (21) relative to the tapered portion (22), while the outer periphery of the small diameter front portion (26) of the nozzle tip (11) is forwardly tapered at the front end thereof so that the front end of the discharge port (19) is enlarged to from an enlarged portion (32). Therefore, the velocity of the compressed air to be jetted out reaches the sonic velocity level by the compressed air being caused to pass through the throat portion (21), and when the air reaches the enlarged portion (32) of the discharge port (19), negative pressure is developed.

On the outer periphery of the plug (12) there are mounted a pair of 0-rings 13a, 13b in spaced apart relation, with a circumferential groove or communicating groove (28) formed between the pair of 0-rings 13a, 13b. Aforesaid liquid introduction path (16) is open into the communicating groove (28). The plug (12) has a center hole (15) in the center thereof at the front end side, there being provided a communicating hole (29) which communicates between the center hole (15) and the communicating groove (28). Accordingly, the liquid supplied into the liquid introduction path (16) is guided into the liquid passage hole (23) of the nozzle tip (11) after passing through the communicating groove (28), communicating hole (29), and center hole (15) is that order.

Now, if operation is started by supplying liquid (liquid pressure = 0) and compressed air to the nozzle assembly of the above described construction, the compressed air sucks liquid droplets thereinto from the front end opening (24) of the nozzle tip (11) as it is jetted out from the discharge port (19), so that it becomes a jet stream of a gas-liquid mixture. At this time, droplets of liquid are sheared by the compressed air into fine particles. Jet streams of a gas-liquid mixture discharged from the individual nozzle heads impinge against each other at one point (A) on the longitudinal axis (X-X), whereby a process of mutual shearing is repeated and simultaneously a supersonic wave of 20,000 - 40,000 Hz is generated, with the result of the droplets being reduced to finer particles. Thus, an ultrafine mist composed of microfine particles is released forward.

(Experimental Example 1)

With careful attention directed to the fact in the nozzle assembly of the above described construction, the angle of taper (α) at the front end portion of the nozzle top (11) is a factor having an important bearing on the flow pattern of compressed air and the magnitude of the resulting negative pressure, the present inventor conducted experiments with a variety of changes in the angle of taper (α) and found out several facts of great interest. The experiments are explained in detail hereinbelow.

Experiment Conditions

Nozzle tips, each having a front end diameter of 1.3 mm and a liquid passage hole diameter of 0.4 mm, were mounted to a double head jet nozzle body (1) having a pain of discharge ports (an inter-discharge port distance: 8 mm, an intersecting angle of (β): 120°), in such a way that the front end

of each nozzle tip (11) projected forward 0.3 mm from the corresponding discharge port (19) of the nozzle body (1) and that the throat portion (21) between the nozzle body (1) and the nozzle tip (11) had a sectional area of 0.5 mm^2 for passage of compressed air. The angle of taper (α) at the front tapered portion of the nozzle tip was changed in various ways in order to find out the relationship between the angle of taper (α) and maximal particle diameter (Fig. 5), the relationship between air pressure and liquid atomization rate (Fig. 4b), the relationship between liquid atomization rate and air consumpton (Fig. 6), and particle diameters in mists produced (Figs. 7a and 7b). The liquid pressure was set at 0, and the height of liquid suction at 100 mm.

Experimental Results

As can be seen from Fig. 5, under the air pressure condition of 3 kg/cm^2, the maximal particle diameter was more than 50 microns (with mean particle diameter of more than about 10 microns) if the angle of front end taper (α) was less than 16° or in excess of 24°, necessary conditions (maximal particle diameter of not more than 50 microns) for an ultrafine mist being not met. Where the angle of taper (α) was in the vicinity of 20°, the maximal particle diameter was reduced to a minimum, say, about 30 micron (with mean particle diameter of 8 microns). Where the angle of taper (α) was within the range of 16° - 24°, the conditions for an ultrafine mist were satisfied. This can be explained by the fact that as Fig. 5 shows, where the angle of taper was in the vicinity of 20°, drops of liquid sucked under a negative pressure were first diverged, but were subsequently caused to impinge upon one another in a well contracted condition under currents of air discharged at a supersonic velocity. That is, if the taper angle (α) was excessively small, currents of air discharged were diverged under the influence of the circumjacent air resistance, and accordingly the jet streams were also diverged and slowed down, so that drops of liquid became coarse. If the taper angle (α) was excessively large, compressed air was separated without being allowed to run along the tapered portion, and therefore jet streams were not well contracted. Thus, the density of impingement energy was substantially reduced with the result of liquid drops becoming coarse.

On the basis of the above described results, it can be said that if the angle of taper (α) at the front end of the nozzle tip is set within the range of 16° - 24°, it is possible to obtain an ultrafine mist with a maximal particle diameter of not more than 50 microns. The provision of a liquid passage hole in the nozzle tip at the front end side thereof has such an effect that the higher the pressure of compressed air, the larger is the negative pressure in the liquid passage hole. Thus, it is possible to increase the liquid atomization rate in proportion to the rise in the air pressure The present invention is based on these experimental results.

Fig. 6 shows, by way of example, the relationship between liquid atomization rate and air consumption in the case where the taper angle (α) is set at 18°. In this case, atomization starts under an air pressure (Pa) of 1 kg/cm^2, and the liquid atomization rate continues to increase notably in relation to the rate of air consumption until an air pressure of 2 kg/cm^2 is reached. When air pressure is increased to a level of more than 2 kg/cm^2, the rate of air consumption tends to increase in proportion to the rise in air pressure. Where the air pressure is between 1 kg/cm^2 and 2 kg/cm^2 there is present no sufficient negative pressure to provide any sufficient shearing action of sucked liquid droplets; therefore, the liquid drops are rather coarse the even after their impingement the maximal particle diameter is in the vicinity of 60 microns, a value somewhat larger than the maximal particle size for an ultrafine mist. However, where the air pressure is greater than 2.5 kg/cm^2, there is present a negative pressure corresponding to the liquid atomization rate, so that the maximal diameter of liquid particles after impingement is not more than some 35 microns, a perfect ultrafine mist being thus obtained.

Fig. 4b shows the Fig. 6 data in terms of the relations between air pressure and atomization rate. An ultrafine mist is produced when the pressure of compressed air is more than 2.5 kg/cm^2, the Sauter mean particle diameter being 10 microns. Where the pressure is less than 2.5 kg/cm^2, the mean particle diameter, at 12 microns, is slightly coarser. That is, even at on/off stages for nozzle operation, no coarse particle mist is produced, there being no or little possibility of the mist wetting the floor and any other circumjacent surface.

In the above described experiment, jet streams of a gas-liquid mixture were jetted out simultaneously from a pair of discharge ports so that they were impinged against each other. In order to further clarify the fact that particle diameters of the mist produced in the above case were very fine and uniform, the above results were compared with those obtained in the case where one of the discharge ports were sealed and jetting was effected from the other discharge port only. Fig. 7a shows results of atomizing operation with a single head nozzle, and Fig. 7b shows results of operation with a double head nozzle. In both cases, examination was made under an air pressure of 3.0 kg/cm^2. In the case with the single head nozzle, there were

present coarse particles having a maximum particle diameter of more than 90 microns, whereas in the case with the double head nozzle the maximum particle diameter was of the order of 35 microns at most. In the latter case, more than one half on the particles produced were several microns in particle diameter and some 95 % of the particles produced were ten and odd microns in particle size, the particles as a whole being very fine and uniform.

(Experiment 2)

In succession to Experiment 1, the present inventor conducted a second experiment. Attention was paid to the fact that the amount of projection (δ) from the nozzle body (1) of the nozzle tip (11) at the front end thereof is another factor which determines the magnitude of a negative pressure produced as a result of compressed air passage. In this experiment, the amount of such projection was changed in various ways. It was found that where the amount of projection was within the range of 0.3 - 0.8 mm, atomization could be effected most steadily.

Experiment Conditions

The experiment conditions applied were basically same as those in Experiment 1. In this case, however, the angle of taper at the front end of the nozzle tip (11) was set at 18¶ , and the amount of projection (δ) was varied in several ways.

Experimental Results

In the above experiment 2, the pressure of compressed air was first set at 3.0 kg/cm^2, and the amount of projection of the nozzle tip front end was increased sequentially from zero to 0.3 mm. Fig. 8a shows the condition of gas/liquid flow in the case where the amount of projection was zero, and Fig. 8b shows the condition of gas/liquid flow in the case where the amount of projection was 0.3 mm. As is apparent from Fig. 8a, where the projection amount was zero, a negative pressure is produced as compressed air is jetted out from the discharge port (19) at a supersonic velocity, and simultaneously upon liquid drops being sucked from the front end opening (24) of the liquid passage hole (24), the liquid is once drawn into the discharge port (19) and then jetted out in conjunction with compressed air. This phenomenon diminishes gradually as aforesaid projection amount is increased, and almost ceases to exist when the amount of projection is increased to about 0.3 mm.

If such phenomenon as shown in Fig. 8a develops, there arises a serious problem which may adversely affect the stability of atomization. That is, if such phenomenon develops, impurities contained in the liquid, such as silica, silicaum, and magnesium, deposit on the sides of the nozzle tip with time, with the result that the desired atomization rate relative to the predetermined pressure of compressed air cannot be maintained. Fig. 9a shows such unfavorable results. In this instance, while the atomization rate is set at 2.0 ℓ, it is apparent that actual rate of atomization is scattered on both the + side and the - side, with 2.0 ℓ as a border line. As deposition of such impurities increases, there will develop a problem of blinding with the discharge port (19).

If the amount of projection is set at about 0.3 mm as shown in Fig. 8b, the effect of a negative pressure, if any, is insignificant and drops of liquid sucked from the liquid passage hole (23) do not spread except on the front end (33) of the nozzle tip; therefore, if such impurity deposition does occur at all, it only affects the tip front end (33), it being very easy to remove such deposit.

Therefore, the flow of liquid drops is stabilized so that a uniform atomization rate can be assured. Fig. 9b shows the results obtained in the case where the nozzle in Fig. 8b was used. It can be clearly seen that the rate of atomization corresponds generally to the atomization rate setting of 2.0 ℓ/hr.

Hence, it is desirable that the amount of projection at the front end of the nozzle tip be set at more than 0.3 mm, but with the increase in the amount of such projection, particle diameters in a mist tend to become larger. In order to obtain an ultrafine mist, there is a certain limitation on the quantity of such projection.

In view of these facts, the relationship between the quantity of projection (δ) at the front nozzle tip end and mist particle diameter was examined using the pressure of compressed air as a parameter. Fig. 10 shows the results thereof.

As Fig. 10 shows, where the quantity of projection is within the range of 0.3 mm - 0.8 mm , the maximal particle diameter is 35 microns to less than 50 microns, necessary conditions for an ultrafine mist being fully met. However, if the quantity of projection is in excess of 0.8 mm, the maximum particle diameter is more than 50 microns, said conditions being not satisfied.

Therefore, an optimum range of nozzle tip front-end projection lengths is from 0.3 to 0.8 mm.

(Experiment 3)

The prior-art nozzle arrangement shown in Fig. 12 involves a difficulty that a temperature drop may occur as a result of compressed air expansion in the discharge port (19), there being possibilities of liquid drop freezing at the discharge port. Experiments were made in order to find how well this problem could be solved by this invention. The results were found satisfactory.

In this experiment, the prior-art nozzle in Fig. 12 and the nozzle employed in Experiment 2 (with the quantity of nozzle tip projection set at 0.3 mm) were both employed, and droplet freeze initiation temperatures were compared between the two nozzles while varying compressed air temperatures. The results are shown in Fig. 11. As can be seen, if the air pressure is more than some 3 kg/cm^2, freezing starts at some 17°C a below with the prior-art nozzle, whereas freezing starts at about 8°C with the embodiment of the invention. In other words, the compressed air freezing temperature observed with the nozzle of the invention is about 9°C lower than that observed with the prior-art nozzle. Therefore, the nozzle in accordance with the invention is advantageous in that no preheating of compressed air is required in a normal range of uses.

Although the present invention has been fully described by way of example with reference to the accompanying drawings, it is to be noted here that various skilled in the art. Therefore, unless otherwise such changes and modifications depart from the scope of the present invention, they should be construed as included therein.

Claims

1. An atomizer nozzle assembly including a nozzle body (1) having a plurality of nozzle heads (10) arranged in equally spaced relation around a longitudinal axis (X - X) thereof, each of the nozzle heads (10) having a mounting hole (14), a nozzle tip (11) mounted in said each mounting hole (14) and having a liquid passage hole (23) opening at the front end thereof, an air jet passage (18) defined between said each mounting hole (14) and the outer periphery of said each nozzle tip (11), the nozzle tips (11) being so arranged that their respective longitudinal axes (Y - Y) converge at a point (A) on said longitudinal axis (X - X), whereby as currents of compressed air are caused to jet out toward the point (A) on said longitudinal axis (X - X) passing through the air jet passages (18), they suck liquid thereinto through the respective front end openings of the liquid passage holes (23) to form jet streams of a gas-liquid mixture so that the jet streams impinge against one another at the point (A) on said longitudinal axis (X -X), thereby producing an ultra fine mist of liquid, characterizing in that the liquid passage hole (23) of said each nozzle tip (11) extending along the longitudinal axis (Y - Y) of the nozzle tip (11) and having its front end opening (24) centrally formed in a front end fare (33) of the nozzle tip (11), an outer periphery of a forward end portion of said each nozzle tip (11) being tapered, angle of taper (α) thereof being 16° - 24°.

2. An atomizer nozzle assembly as set forth in claim 1, wherein said forward end portion of said each nozzle tip (11) projects from the front end (34) of said each nozzle head (10), the length of said projection being 0.3 - 0.8 mm.

Fig. 1

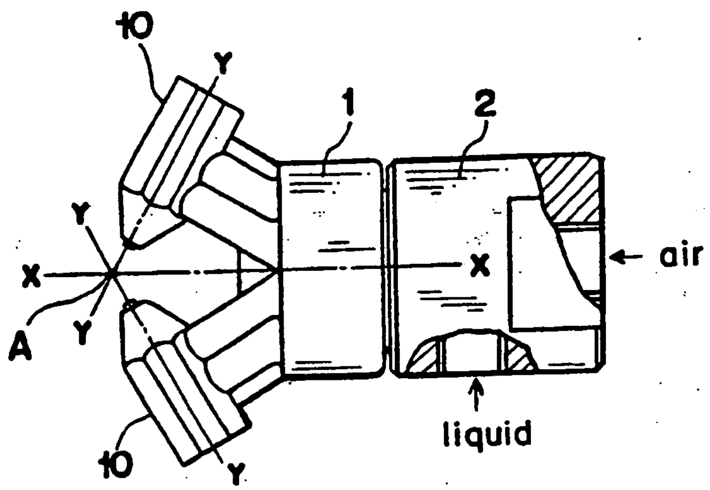


Fig. 2

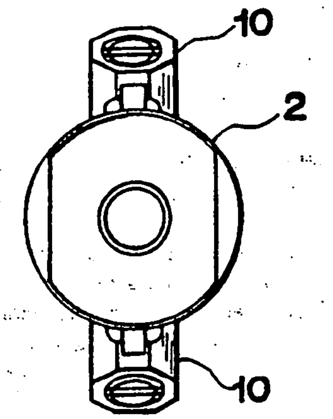


Fig. 8a

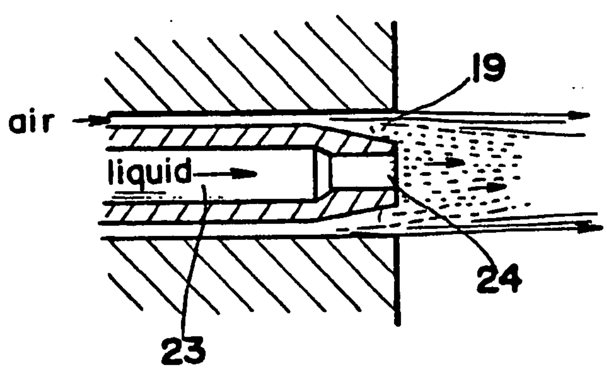


Fig. 8b

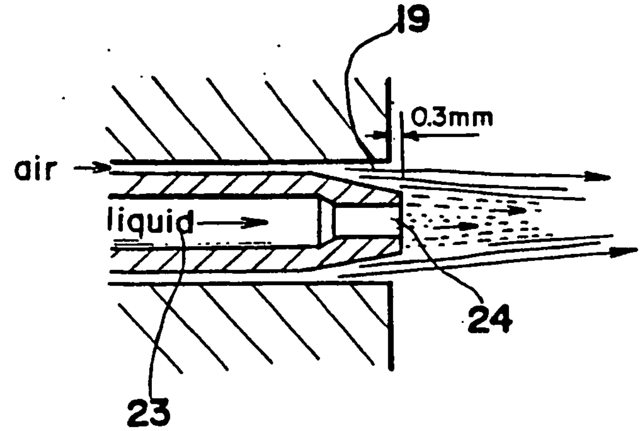


Fig. 3a

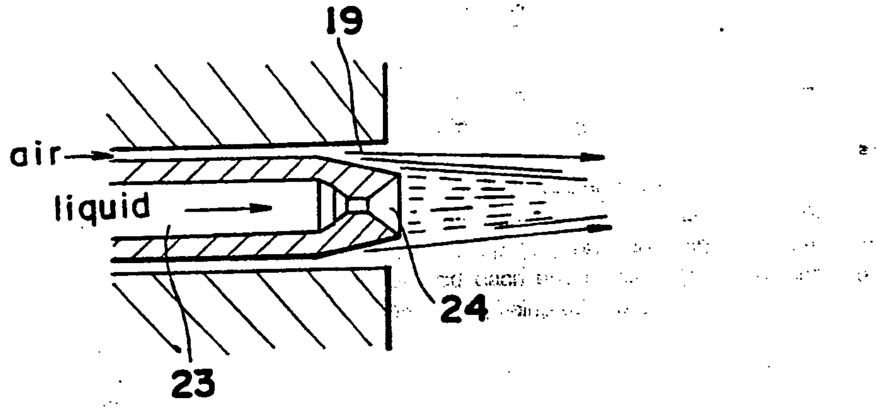

19
air
liquid
24
23

Fig. 3

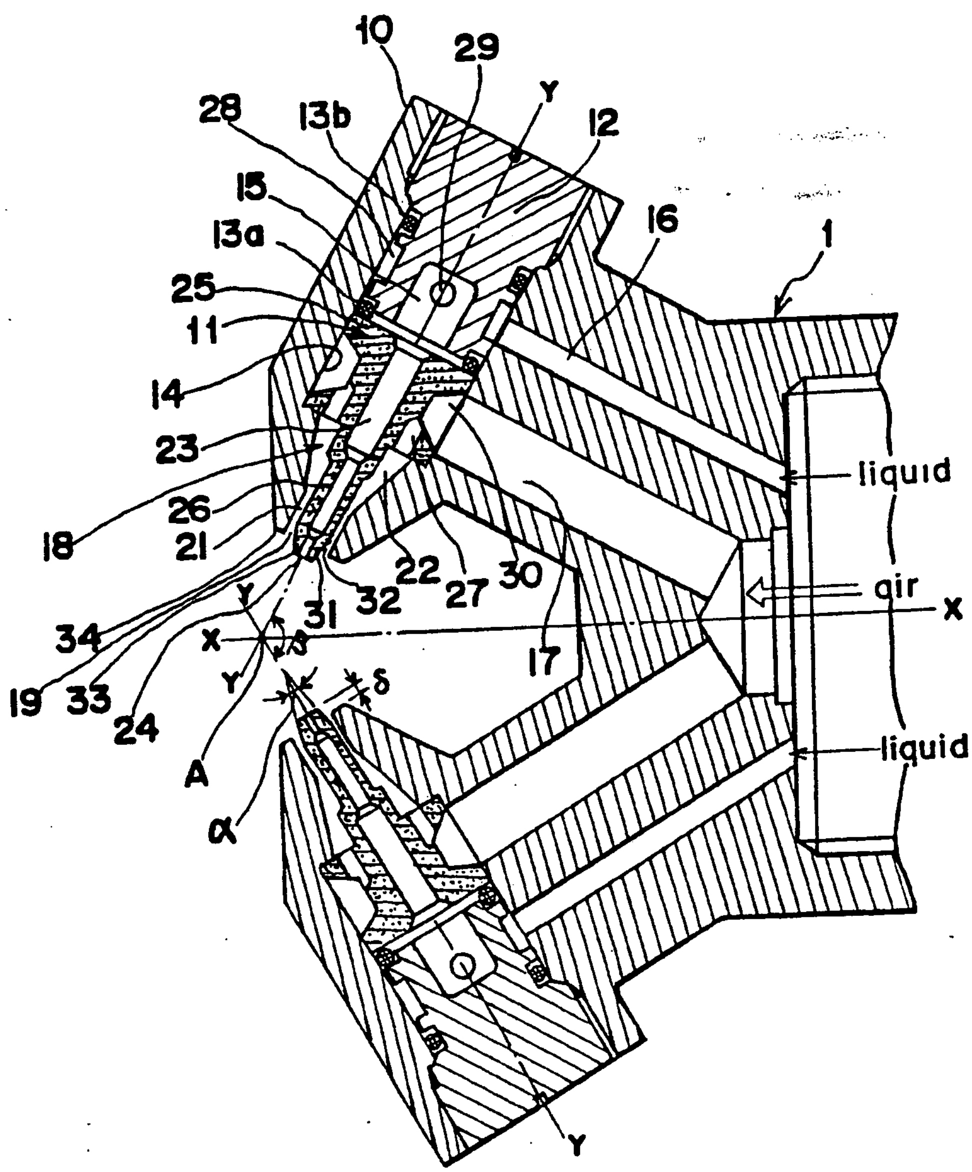

10
29
28
13b
Y
12
15
13a
16
1
25
11
14
23
liquid
26
18
21
22
27
30
air
X
Y
31
32
34
X
β
17
Y
δ
19
33
24
A
liquid
α
Y

Fig. 4a

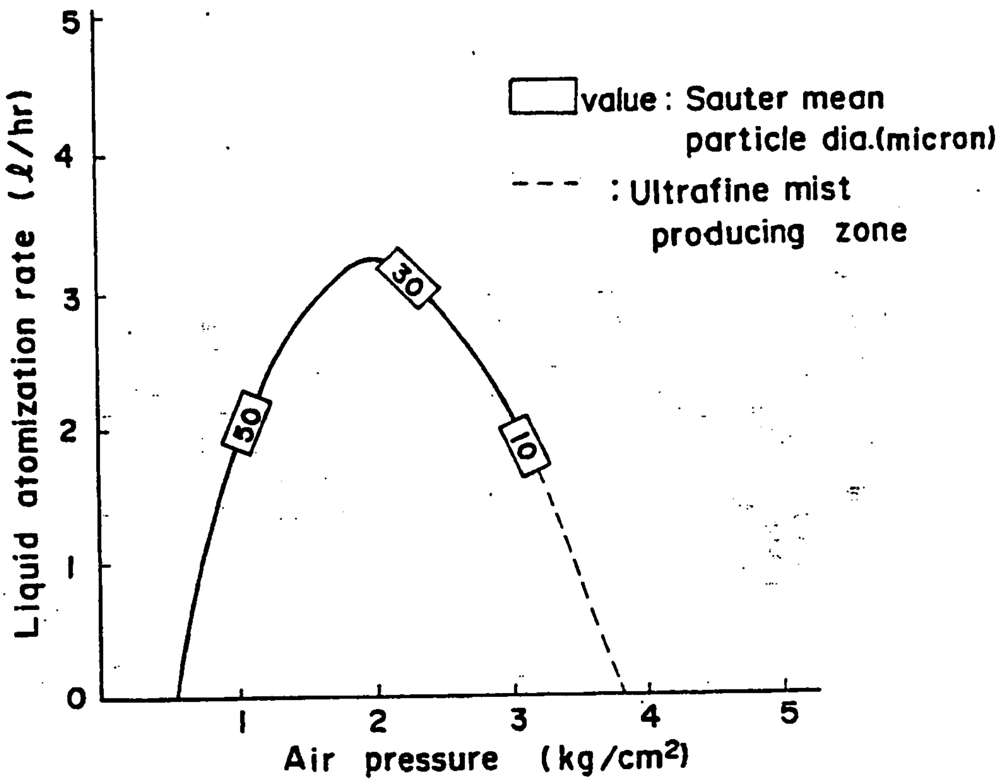

5
4
3
2
1
0
Liquid atomization rate (ℓ/hr)
value : Sauter mean particle dia.(micron)
: Ultrafine mist producing zone
30
50
10
1
2
3
4
5
Air pressure (kg/cm2)

Fig. 4b

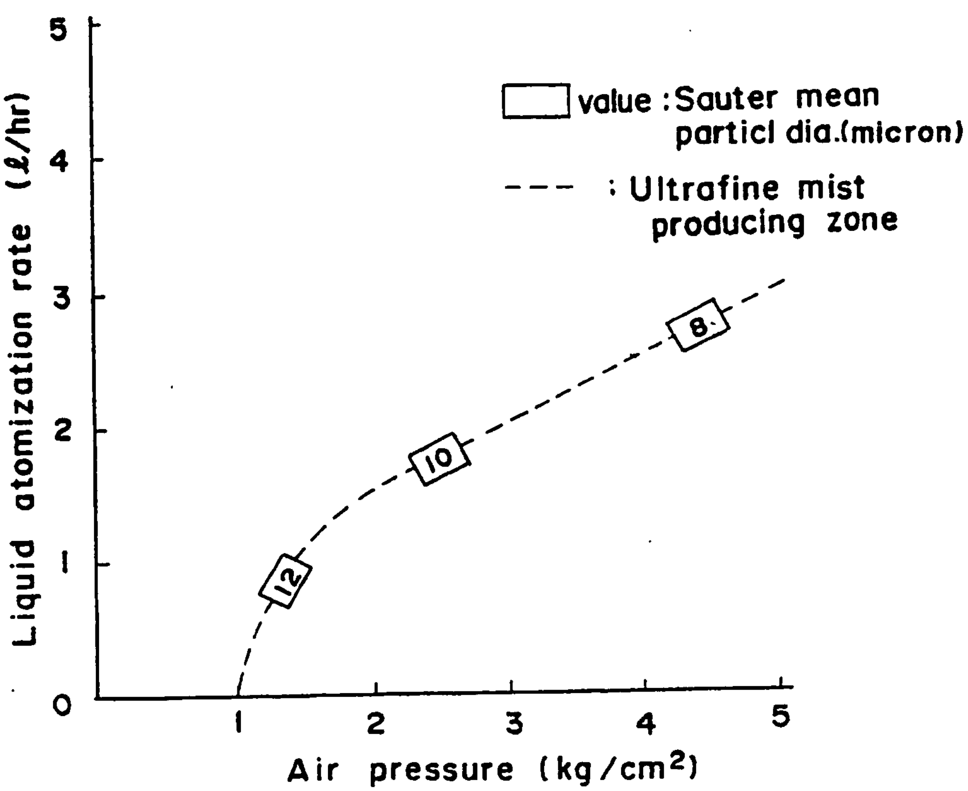

5
4
3
2
1
0
Liquid atomization rate (ℓ/hr)
value :Sauter mean particl dia.(micron)
: Ultrafine mist producing zone
8
10
12
1
2
3
4
5
Air pressure (kg/cm2)

Fig. 5

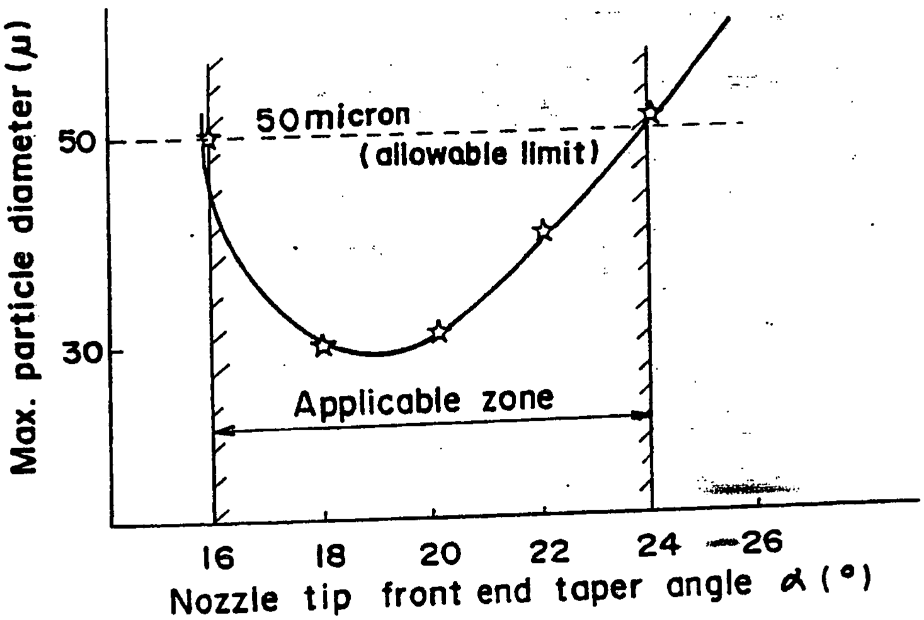

Max. particle diameter (μ)
50
30
50 micron
(allowable limit)
Applicable zone
16
18
20
22
24
26
Nozzle tip front end taper angle α (°)

Fig. 6

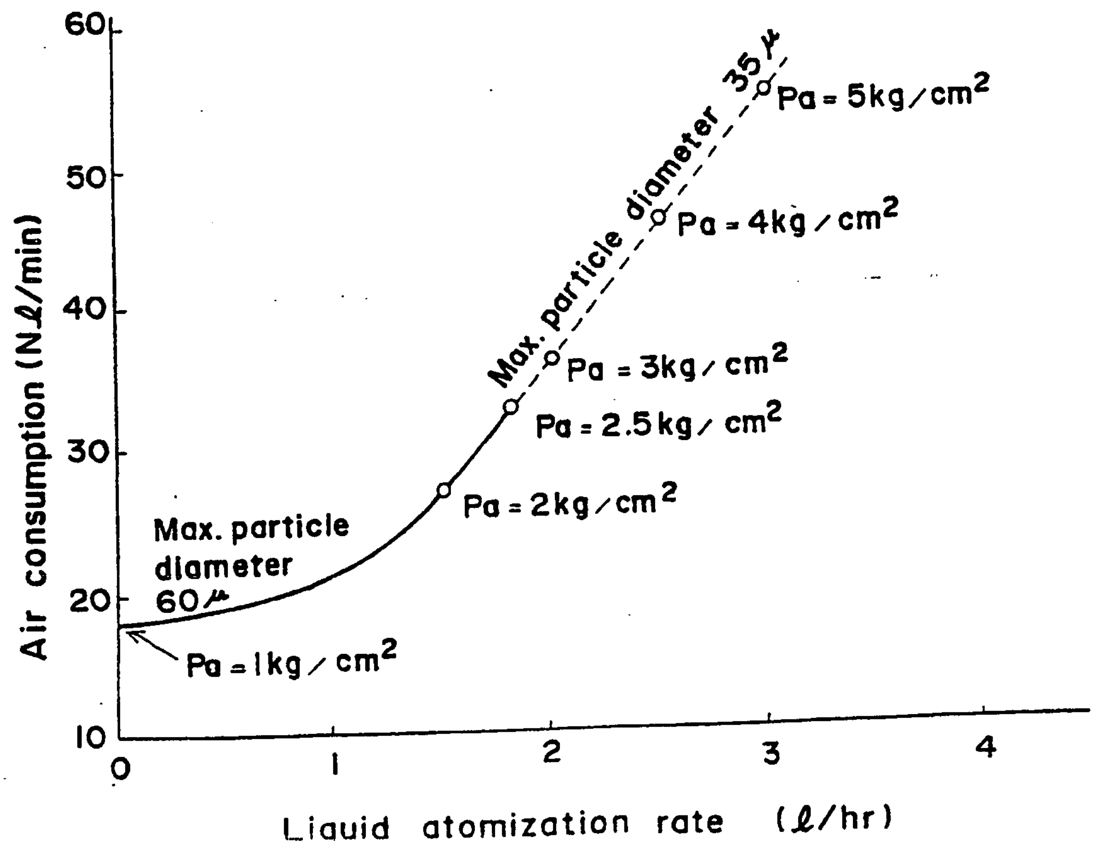

Air consumption (Nℓ/min)
60
50
40
30
20
10
Max. particle diameter 35μ
Pa = 5kg/cm2
Pa = 4kg/cm2
Pa = 3kg/cm2
Pa = 2.5kg/cm2
Pa = 2kg/cm2
Max. particle diameter 60μ
Pa = 1kg/cm2
0
1
2
3
4
Liquid atomization rate (ℓ/hr)

Fig. 7a

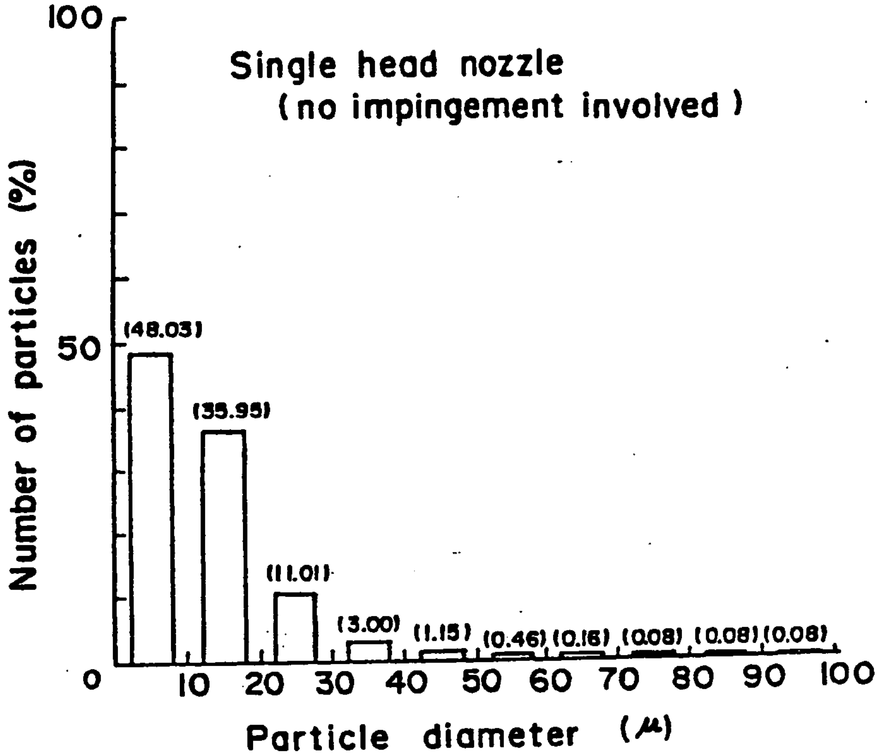

Single head nozzle
(no impingement involved)
Number of particles (%)
100
50
0
(48.03)
(35.95)
(11.01)
(3.00)
(1.15)
(0.46)
(0.16)
(0.08)
(0.08)
(0.08)
10 20 30 40 50 60 70 80 90 100
Particle diameter (μ)

Fig. 7b

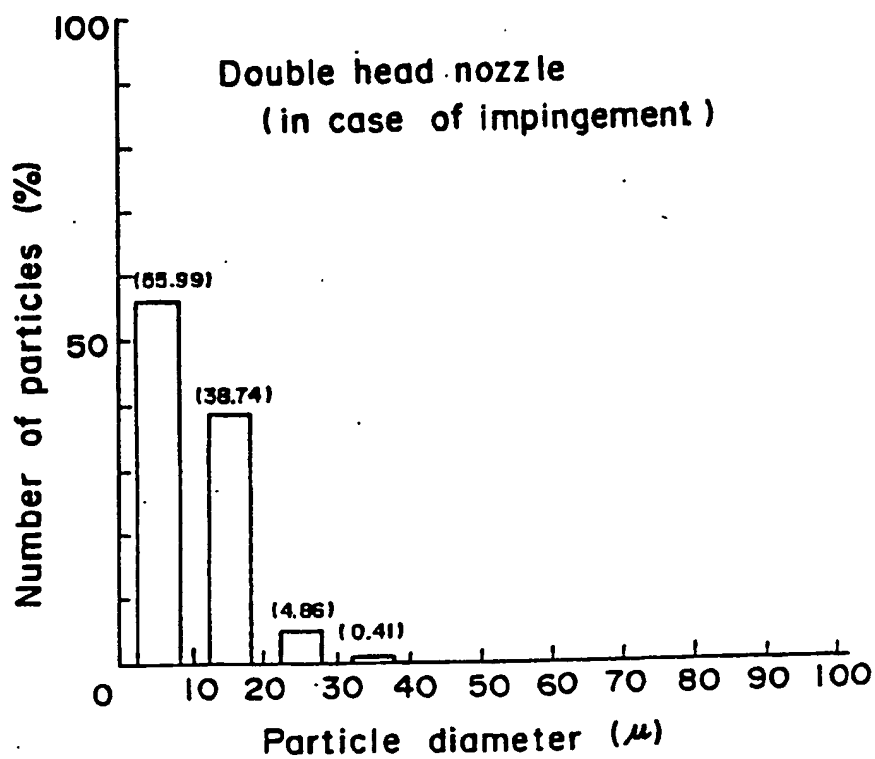

Double head nozzle
(in case of impingement)
Number of particles (%)
100
50
0
(55.99)
(38.74)
(4.86)
(0.41)
10 20 30 40 50 60 70 80 90 100
Particle diameter (μ)

Fig. 9a

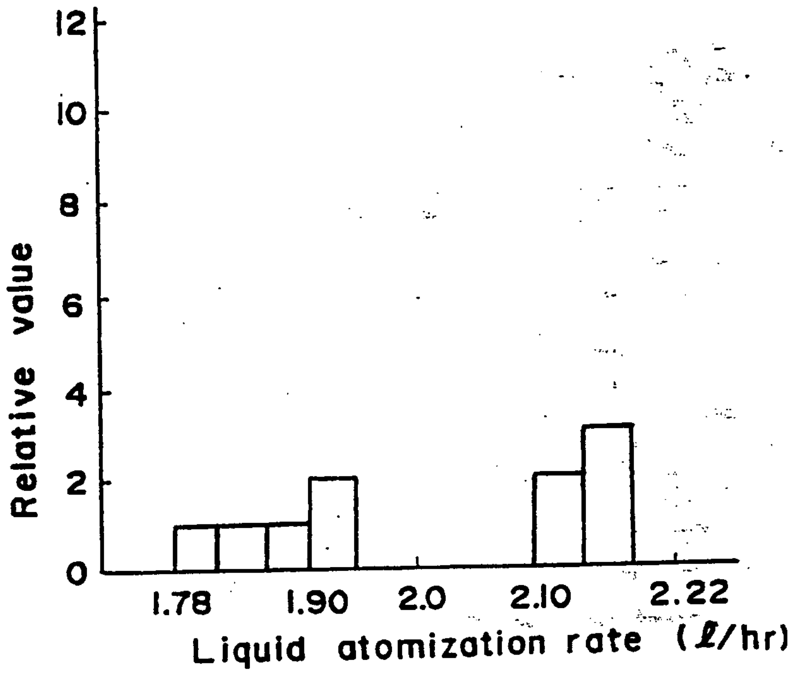

12
10
8
6
4
2
0
Relative value
1.78
1.90
2.0
2.10
2.22
Liquid atomization rate (ℓ/hr)

Fig. 9b

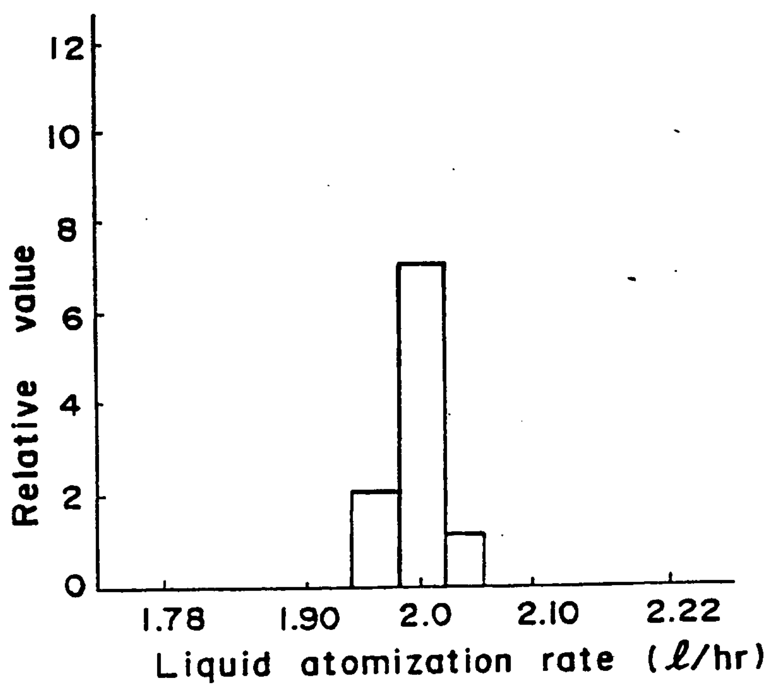

12
10
8
6
4
2
0
Relative value
1.78
1.90
2.0
2.10
2.22
Liquid atomization rate (ℓ/hr)

Fig. 10

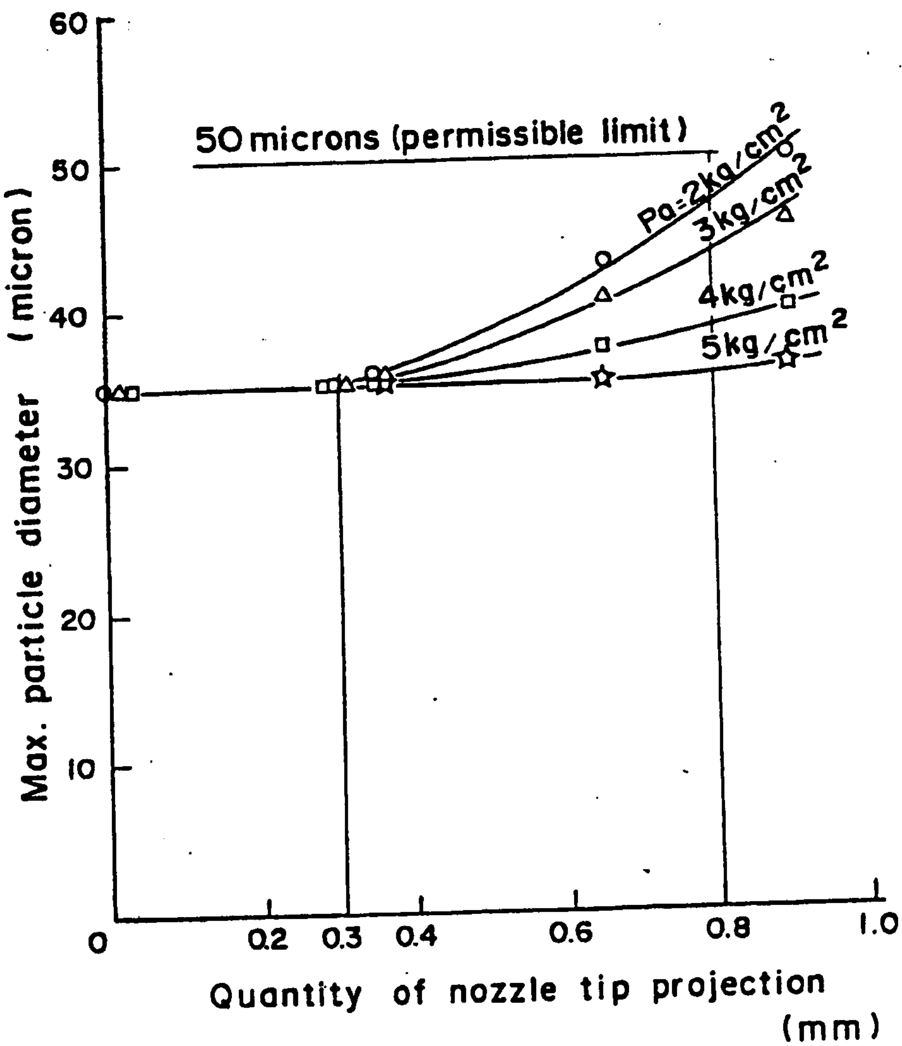

50 microns (permissible limit)
Pa=2kg/cm2
3kg/cm2
4kg/cm2
5kg/cm2
Max. particle diameter (micron)
60
50
40
30
20
10
0
0.2
0.3
0.4
0.6
0.8
1.0
Quantity of nozzle tip projection (mm)

Fig. 11

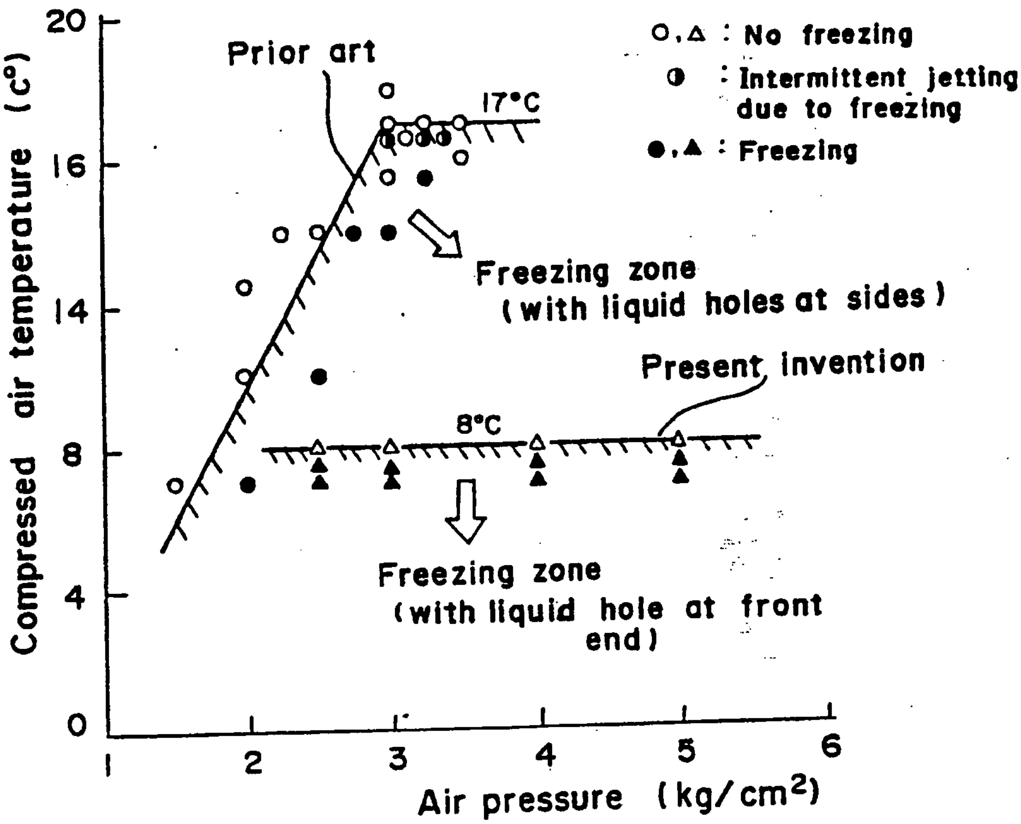
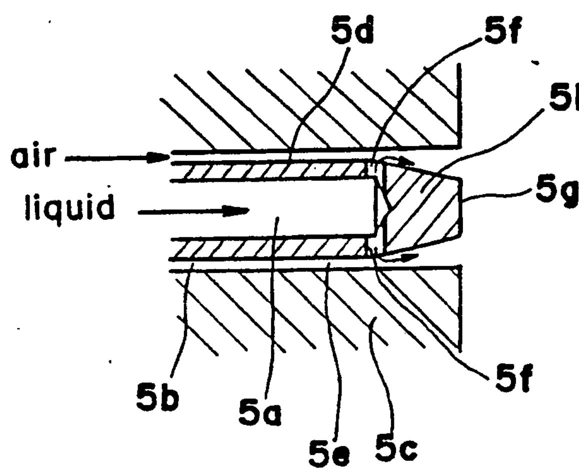


Fig. 12 PRIOR ART



European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 87108288.9

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	GB - A - 2 162 769 (VORTEC CORP.) * Page 2, line 74 - page 3, line 26; fig. 1-3 * --	1	B 05 B 7/08
Y	EP - A1 - 0 046 608 (IKEUCHI) * Page 7, line 2 - page 13, line 12; page 18, line 26 - page 19, line 18; fig. 3,9, 10 *	1	
D	& JP-A2-57-42 362 --		
A	US - A - 4 284 239 (IKEUCHI) * Abstract; fig. 1-9 *	1	
D	& JP-A2-55-49 162 ----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			B 05 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	08-09-1987	KUTZELNIGG

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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